Development of a Multi-Purpose Roasting Machine.

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ABSTRACT

In order to reduce the problems of efficiency, hygienic level of product, and time of roasting which have been faced by yam, maize, plantain roasters and other food items, a multi-purpose roasting machine was designed and fabricated. The roasting machine was design in such a way that it can accommodate ten (10) food items at a time. A chain and sprocket with a pedal mechanism was incorporated to provide smooth and better speed of roasting. The mechanism is continuously rotating the food items in the roasting chamber and simultaneously powering the blower thereby reduces the stress of carrying out the operations. A charcoal chamber adjusting mechanism was also incorporated in the machine to help in varying the heat intensity from the charcoal chamber to the food items. The machine was tested with three different food items which include: maize, yam and plantain and the results obtained was compared with common and traditional method of roasting. This machine was observed to have efficiency of 94% in terms of uniformity of roasting of the entire food while the traditional method of roasting has 75%. Moreover, about one-third (1/3) of the time used by common method was used by the newly developed roasting machine. This machine is avoidable, durable, and reliable with less stress and time of operation.

(Keywords: multi-purpose, food, roasting machine)

INTRODUCTION

The processing of food items has become an important aspect in human daily consumption of food. It is the methods and techniques used to transform raw ingredients into consumable food or a process by which a raw food is transformed to edible food for consumption by humans or animals either in the home or by the food processing industry. This processing involves application of engineering technology with the aid of food science, to change or alter the appearance, taste, aroma, shape, or color of selected agricultural food produce in order to satisfy human daily needs of food (Fellows, 2000). Various techniques are available for food processing, most of which are applied in the food industry. These techniques include ambient temperature processing which involves the raw material preparation, size reduction, mixing, and processing by application of heat.

Roasting is another cooking method that uses dry heat, whether an open flame, oven, or other heat source. Roasting usually causes caramelization or maillard browning of the surface of the food, which is considered a flavor enhancement (Wikipedia, 2010). Roasting, as the word implies, is the working mechanism by which the food product material are thermally subjected into irreversible structural changes and reduction of moisture contents purposely to bring about digestible content for human consumption (Fellows, 2000). The method of applying heat to process foods seems to be the most prominent method of processing food in Nigeria. It is common household and as the rural dwellers, who themselves through farming, take to roasting as an important food processing techniques, this is a viable tool helping them have access to quality roasted produce e.g. yam, maize, plantain, etc.

Maize (*Zea mays*) is the most important cereal crop in the world after wheat and rice with regard to cultivation areas and total production (Abdu Rahaman and Kolawole, 2006). For the purpose of fresh roasted maize, sweet corn is usually best harvested just before the stigma dries out or as soon as they turn brown for fresh corn eaten of the cob, mostly when majority of the cobs are

fairly close to maturity. Then the husks are pecked off and ready for roasting for consumption purpose.

Yam is another economically useful plants belonging to the genes dioscorea, or the tubers or rhizomes of these plants (Jimoh, et al., 2008). The yam tuber is essentially a starchy or carbohydrate food, its principal nutritional function being the supply of calories to the body. The yam tuber is prepared for consumption in a variety of ways including boiling, frying, baking and roasting. Roasted yam recently has become a popular street or fast food in urban area of Nigeria.

Plantain is a starchy, less sweet variety of banana which cannot be eaten raw (unlike banana) because it contains indigestible tannins (FAO, 2006, Akomolafe and Aborisade, 2007). About 80% of banana grown throughout the world are of the plantain variety (Castello, 2006). One large plantain is about 26cm in length and 6.5cm width, packs with 602mg of potassium and carries about 140 calories (Izunfuo and Omuaru, 2006). It contains 2 grams of protein and 4 grams of fiber, and for this reason it was consider and important food to boost the health of malnourished children and recommended by doctors for those whose potassium is low (Adegboyega, 2006). In many parts of Africa, cooking banana is prepared by boiling or steaming, mashing, baking, drying or pounding to fufu (FAO, 2010). It is sometime fried or baked (roasted).

Roasted plantain, yam, and maize are becoming popular as form of refreshment and sometimes major food in Nigeria. Sellers position themselves close to government ministries and agencies or other private organizations for easy accessibility (Mato and Onajin-Obembe, 2008).

Traditional way of roasting that people are used to is always very stressful because of processes involved, which include regular blowing of air to ensure constant heat supply from heat source (charcoal) and regular changing of the position of the food item to prevent from burning (Mato and Onajin-Obembe, 2008). Moreover, charcoal grilling produces the highest of polycyclic aromatic hydrocarbon. This is a large group of organic chemical containing two or more fused aromatic ring made of carbon and hydrogen (Tzanakis, et al., 2001). It is a known respiratory toxicant and has been associated with respiratory symptoms, bronchial anthracosis, as well as chronic obstructive pulmonary diseases (Ellegard, 1996). Despite all the problems and risks associated with the business, some people still use the means as source of earning their living (Pearce and Agboh-Bankole, 1988). In view of these challenges there is a need to develop a roasting machine that will be able roast yam, maize and plantain with higher efficiency and speed in a hygienic environment with less stress.

DESCRIPTION OF DEVELOPED MACHINE

The multipurpose roasting machine is made up of roasting chamber, heating chamber, two blowers, and driving (power transmission) mechanism. The roasting chamber houses ten food hangers, five on each side of the chamber. The food hanger is use to hold the food items and the hangers were subjected to continuous rotation for uniform and smooth roasting.

The heating chamber is comprised of charcoal cabinet and ash collector rigidly joined together with a frame. The ash tray was designed to collect the ash from the burnt charcoal. It was designed in such a way that it comes directly below the charcoal box. The ash tray supports are rigidly joined together with charcoal chamber. This support was made to rest on adjusted mechanism to move both charcoal chamber and the ash tray to specific distance to the food item.
The blowers that are on both side of the lower part of the machine supply continuous air to the heating chamber to maintain the heat intensity through continuous rotating fan that was channel toward heating chamber. Chain and sprocket mechanism is the mean of power transmission mechanism that was used to supply rotational motion to the fans and food hangers through the shafts in the machine

MULTI-PURPOSE ROASTING MACHINE DEVELOPMENT

In the development of a multi-purpose roasting machine, design, fabrication, and the performance evaluation was carried out.

Design Calculation

In designing the main housing that can accommodate ten (10) food items at the time, sample of the concerned food items which include maize, plantain and slice of yam were

identified to be able to ascertain various sizes of the food items. The lengths of the maize, yam and plantain are (40 – 50) mm, (20 – 40) mm, and (60 – 80) mm respectively; these lengths were used as the basis for the design of the housing of the roasting machine.

The framework of the machine is made from a square pipe of the dimension 4 x 4cm and is made from mild steel. It is constructed into a box-like structure with stands, the mass of materials used for the frame is determined using the relation ρ = mv where ρ = density of the material in kg/m^3 or g/cm^3, m = mass of material in kg or g and v = volume of material m^3 or cm^3. The density of mild steel is 7820kg/m^3 while the volume is gotten from the relation V = volume of outside diameter – volume of internal diameter (square pipe), V was gotten to be 113.1cm^3, therefore the mass was estimated to be 0.884kg and the total mass for the four legs to be 3.54kg. Mass of material used in making the breadth was estimated to be 0.512kg and for the four legs 2.05kg.Mass of material used for the legs was obtained from the same relation as above and the mass was estimated to be 0.942kg while the total mass for the four legs was 3.77kg.

In the designing the blower housing, a diameter of 5mm was used with a thickness of 0.1mm, the volume was obtained from the relation V= (ΠD^2 x t)/4 found to be 19.63cm^3 while the mass was estimated to be 0.153kg. The charcoal box is constructed with adjusted mechanism with dimensions quite lesser than that of the roasting chamber; the mass was obtained to be 2.53kg.
Ratio of output speed n_2 to input speed n_1 is calculated by $\frac{n2}{n1} = \frac{Nt1}{Nt2}$, where Nt_1 and Nt_2 represent the number of the teeth on the input and output sprockets, respectively.

$Nt_1 = 43$

$Nt_2 = 14$

Given the speed of the input sprocket to be 20 rev/min. from the relation n_2= 61rev/min. For the tentative center distance of 160mm, chain length was calculated using the relation L = 2c + π (R1 + R2) + $\frac{(R2-R1)2}{c}$ and was 700.2mm. This is the maximum length of chain used for the input and output sprocket.The chain cross-sectional area is obtained from the relation A = wt where w = width t = chain thickness, to be 140mm^2. The tension in the chain was also obtained 280N.

In obtaining the weight of sprockets, the relation, Mass of the sprocket = volume x density is used. For the smaller sprockets, Diameter of sprocket = 6cm, Width of sprocket, t = 0.8cm, Volume of material used for the sprocket = 22.62cm^3, Weight of the sprocket = 1.73N. For larger sprockets, Diameter of sprocket = 17cm, Width of sprocket, t = 0.8cm, Volume of material used for the sprocket = 181.6cm^3, Weight of the sprocket = 13.9N.

The torque is estimated to be 7.60Nm from the relation T = (T1 – T2) x $r_1$where r_1 = 85.5 x 10^{-3}m. for the bearing design, Roller bearings were selected; the following gives the data for the selected bearing. Bearing designation: 6305, Bearing diameter: 16mm, Outside diameter: 40mm, Diameter load rating C: 14, 906N, Static load rating Co: 10, 545.89N, Bearing weight: 23N, Bearing life: this is defined as the total number of hours at a given constant speed of bearing operation for the failure criteria to develop.

Knowledge of heat transfer processes is required for the construction of multipurpose roasting machine. The rate at which heat is transferred from heating medium to food by force convection, Heat transfer by convection is measured by the relation $Q = hA(T_w - T_\infty)$, where, Q = Rate of heat transfer, h = convectional neat transfer co-efficient, □ = surface area of heat transfer and $(□_□ - □_\infty)$ = Temperature different.

Fabrication

The selection of a specific material for a particular use is a very complex process. However, the selection of material for the fabrication of multipurpose roasting machine was base on, operating parameters, manufacturing processes, functional requirements and cost considerations (Adewumi, 2007). For the roasting machine to be able to perform effectively within its limited life span, the material was made to be able to adapt to environment, made of suitable strength, stability, heat resistance, hardness, roughness, elasticity, and is of suitable weight (Oke and Ogundare, 2012). The development of the multi-purpose roasting machine with considerable higher efficiency was achieved with the aid of the design, drawing and calculations.
The construction procedures were done in stages starting from the construction of the framework

where the frame was constructed using 4 x 4cm square pipe. The square pipe was marked out accordingly and cut into pieces of different required size based on the design calculation. The pieces were welded together for rigidity, support and stability. Four pieces of the square pipe measure 772mm each to form the stands. Four pieces of the square pipe measures 725mm each to form the front of the frame four pieces of the square pipe measures 420mm each to form the side of the frame. Three sides of the frame were covered with metal sheet while one side is left uncovered simply to create an opening.

The charcoal container was constructed using metal sheet of 2mm thick. The material was measured according to the design size. The charcoal chamber was perforated to allow air from the blower for effective supply of required heat. The ash tray was designed to collect the ash from the burnt charcoal. It was designed in such a way that it comes directly below the charcoal box. The ash tray is to stand on supports that are constructed from metal stripes that run through the length and breadth of the roasting machine so that the tray can slide out from the stands. The ash tray support is rigidly joined together with charcoal chamber. This support was made to rest on adjusted mechanism to move both charcoal chamber and the ash tray to specific distance to the food item.

Twenty small sprockets were welded on the both outside of the roasting chamber, the food hangers were also welded with the sprocket at other side at the interior of the roasting chamber. The food hangers are tiny rods that have cylindrical cross sections made from mild steel. These hangers are used to hold the foods item to be roasted. It protrudes into the roasting chamber and it holds the food produce over the fire. They are designed to rotate alongside the pinions with the speed for effective roasting these hangers are welded firmly to the minor shafts of small sprocket.

Four small sprockets were rigidly welded to the two blower shaft, one each at the extreme end of the two shafts. One big sprocket were welded to driving shaft, which was connected the one of the small sprocket on the blower shaft with the aid of chain. Another chain was used to connect the sprocket on the other side of blower shaft to the one of the sprocket on the second blower shaft. This actually transfers the motion from the driving shaft to the two blower shafts. Two other small sprocket were attached on the driving shaft to transfer the motion from the driving shaft to the sprockets beside the roasting chamber through two connected chains

The blower housing was formed from 2mm thick mild steel sheets. It was measured and folder to form the desired shape and inlet for the incoming air from the impeller. The air was channeled into pipes that had been perforated and inserted into the charcoal box. The size of the holes is about 5mm in diameter. It was placed in the charcoal box at convenient positions so that there could be uniformity in the circulation. The total cost of materials and workmanship of the machine is twenty eight thousand naira (₦38, 0000:00) which is still avoidable to common people compared to stress undergo in the process of roasting these food items.

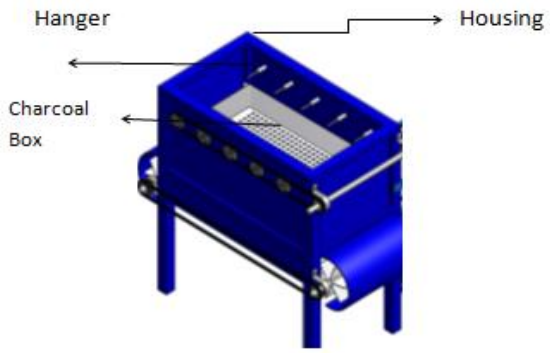

Figure 1a: The Multi-Purpose Roasting Machine.

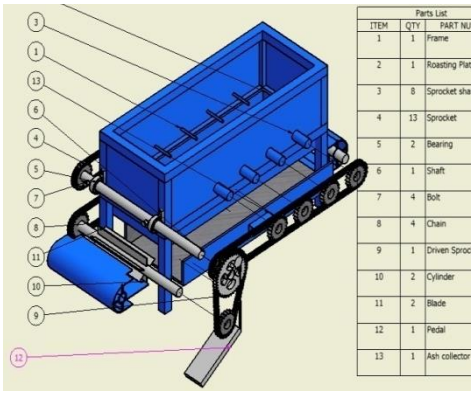

Figure 1b: Exploded View of Multi- Purpose Roasting Machine.

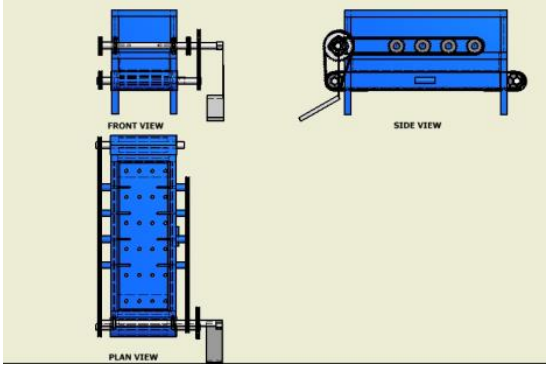

Figure 1c: Orthographic View of the Multi-Purpose Roasting Machine.

PERFORMANCE EVALUATION

The machine was used to test the following food items: yam, maize and plantain. Five test trials were carried out on each set of food item and the average value of the result was used for analysis. The following steps were taken while testing the machine:

(i) The charcoal was ignited and allow to burn for at least five minute for the charcoal to be red heated.

(ii) Roasting chamber was adjusted to appropriate distance for different food items.

(iii) Food items were arranged on the hanger,

(iv) Time taken for each food item to be roasted was taken and the percentage roasted was also determined.

(v) The average results obtained were later compared with the result obtained from the experimental test carried out on traditional method of roasting using the same number of food item for each sample.

RESULTS AND DISCUSSION

From the test results, using maize as a sample, an average roasting time of 21 minutes was obtained from five experiments conducted with traditional method of roasting using 10 cobs of maize, with the average percentage roasted of 60%. Meanwhile an average roasting time of 15 mins was obtained for developed multipurpose roasting machine and the average percentage roasted of 95%.

Yam and plantain follow the same trend with average of 46 mins and 35mins respectively for roasting using traditional method with 65% and 63% performance efficiency. The average percentage of yam roasted is 97% while that of plantain is 94% when the same quantity of food item were roasted with developed roasting machine. Moreover the time for roasting of yam and plantain with this machine was 30 mins and 24 mins, respectively.

These results show that there is a significant improvement on the performance of developed multipurpose roasting machine over the traditional method of roasting generally used. The machine had been able to produce roasted food items at faster rate speed, and in a better hygienic environment.

CONCLUSION AND RECOMMENDATION

The performance test has shown that the use of developed roasting machine had provided hygienic and better roasted food items than the traditional or local method of roasting. The machine can be used to roast other food item with aid of adjuster incorporated into the machine to vary the distance between the food items and heating element. The total cost of materials and workmanship of the machine is thirty eight thousand naira (N 38000:00) which is still avoidable to common people compared to stress undergo in the process of roasting these food items.

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